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HYGIENIC EVALUATION OF MODERN SKI OUTFITS

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-USSR-

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## FOREWORD

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## HYGIENIC EVALUATION OF MODERN SKI OUTFITS

-USSR-

Following is the translation of an article by Corresponding Member of the Academy of Medical Sciences USSR A. A. Minkh, Prof. Yu. V. Vadkovskaya, and Candidate of Medical Sciences A. A. Mironova in Gigiena i Sanitariya (Hygiene and Sanitation), Vol XXV, No 12, Moscow, 1960, pages 39-45.

(From the Central Order of Lenin Institute of Physical Culture and the Institute of General and Communal Hygiene imeni A. N. Sytin of the Academy of Medical Sciences USSR.)

Skiing demands that serious attention be given to clothing, which should aid the organism's adaptation to work under changing climatic conditions, should safeguard against overheating and chilling, should be lightweight, loose, etc. Modern ski outfits have been designed on the basis of skiers' practical experience, but they have not been fully approved from the hygienic point of view.

Our objective was the field study of the hygienic advantages of various ski outfits in wide popular use; on the basis of this study we would make certain recommendations on the choice of outfits, and the reasons for the choice. We tested four types of outfits -- cheviot, flannel, velveteen, and percale combined with cotton underclothing. With the percale outfit, fustian underclothing was added as well. Each outfit was tested six times. The experimental subjects were six students of the Physical Culture Institute; they were of approximately the same age, weight, and skill in sports. Conditions of work, living and nourishment were also equal. The outfits were tested before and after the skiers had covered a distance of five to ten kilometers in a marked-off area. The physiological observations consisted of measuring the temperature of the body and the skin, determining the amount of water-loss, and evaluating the subjective sensations of the skiers. With this there was concurrent measurement of the temperature and relative humidity of the air under the clothing, as well as the dampness of the underclothing at various body regions, and of the underclothing as a whole. Weather conditions were taken into account; during the testing period they were fairly constant -- the air temperature fluctuated between  $-8^{\circ}$  and  $-11.5^{\circ}$ , the relative humidity was

always high, and the speed of air movements did not exceed 2.6 meters/second (the ski run was in a pine forest).

Walking on skis involves a large energy output. Thus, if an average of 384 kilocalories/hour are used up in ordinary walking, then the energy output in ski walking increases to 710-1,076 kilocalories/hour (A. A. Minkh and A. F. Legun). In covering a 10-kilometer distance at a casual pace, the energy output of beginner skiers averages 704.9 kilocalories/hour (Yu. V. Vadkovskaya and A. D. Astaf'ev). Intensive muscular activity induces copious sweating, and this in turn results in significant weight loss. Traversing a 10-kilometer distance results in significant weight loss. Traversing a 10-kilometer distance results in a weight loss of 800-900 grams (A. N. Krestnikov).

Movement on skis is characterized by large heat production which, in spite of the low temperature of the surrounding medium and the air movements, cannot be balanced with the heat loss by means of heat radiation or conservation, because a significant part of the heat is lost as a result of evaporation. In absorbing the sweat, the clothing becomes moist; this is why the heat conductivity of the fabric tissue increases sharply. As long as the skier is active, the moist clothing does not induce chilling of the body, since the clothing is warmed by body heat given off in large quantity by the skin surface. If, however, the speed of action is decreased or especially if the skier stops for a rest or for other reasons, then the organism's heat production falls off, and heat loss begins to exceed heat production. Consequently, chilling of the body occurs; this is detrimental to the skier's general condition, lowers his work capacity, and can result in colds. The skier's clothing must guarantee efficient heat loss on the one hand, and on the other protect him from the cold. Of course, a great many other hygienic and sport requirements must be added to these qualities.

Studies of an organism's heat balance as influenced by physical exercises make use of various indices of which one is the body temperature. In our research, we measured the body temperature orally, since the profuse perspiration made it inconvenient to measure it in the arm-pit. As a result, we established that a moderately-paced ski run over 10 kilometers did not induce any noticeable temperature changes of the body, either on still days or in a strong wind. This was noted in tests with all four types of outfits. An analogous situation was observed among skiers competing at a meet. Body-temperature measurements of 50 skiers, before and after competition, showed that in half of the cases the temperature drops by  $0.1^{\circ}$ - $1.2^{\circ}$ ; in 16 cases, the temperature increases by  $0.1^{\circ}$ - $0.7^{\circ}$ ; in the rest, there was no change. A. N. Krestovnikov also observed a lowering in the body temperature after ski contests, and he explains it as "starting fever" before a competitive meet; as a result of this "fever" the body temperature can be somewhat increased.

The results of measuring skin surface temperature under the clothing, the temperature in the air spaces between the clothing layers, and between the underclothing and the outfit are shown in Table 1. See following page 7 From the table, it is evident that skiing is accompanied by a lowering of the skin temperature, especially on the chest; this latter results from the cooling effect of the oncoming wind. As the ski-run distance is increased, this temperature drop becomes increasingly significant, and after a run of 10 kilometers under the above-mentioned weather conditions, the drop attains the following averages: in the percale outfit (two sets of undergarments as compared to one set with the other outfits), the skin temperature on the chest dropped by  $8^{\circ}$ , and on the back by  $6^{\circ}$ ; in the velveteen and flannel outfits, the corresponding decreases were by  $10^{\circ}$  and  $4^{\circ}$ ; in the cheviot outfit, the decreases were by  $12.3^{\circ}$  and  $6.3^{\circ}$ .

Comparison of the skin temperatures on the chest and on the back showed that, at rest, the difference between them in any outfit does not exceed  $2.1^{\circ}$ . However, after a run of 5-10 kilometers, the difference reaches the following figures: velveteen outfit,  $3.8^{\circ}$ - $4.5^{\circ}$ ; flannel outfit,  $3.4^{\circ}$ - $7.1^{\circ}$ ; cheviot outfit,  $4.6^{\circ}$ - $6^{\circ}$ ; percale outfit -- at first there is an insignificant increase in the indicated differences, and then a decrease.

The change in the skin temperature coincides with the temperature change of the air spaces between the underclothing and the outer garments. While the subject is skiing, the temperature of the air spaces on the chest and back also decreases. Thus, with the percale outfit, after a 10-kilometer ski run, the temperature of the air space on the chest drops by  $12.9^{\circ}$ , and on the back by  $7.8^{\circ}$ ; with the flannel outfit, the corresponding figures are a decrease of  $14^{\circ}$  and  $7.9^{\circ}$ ; cheviot outfit, a drop of  $12.4^{\circ}$  and  $7.2^{\circ}$ ; velveteen, a drop of  $6.9^{\circ}$  and  $4.1^{\circ}$ . The difference in temperature of the air space on the chest and on the back before tests in the various outfits is  $0.4^{\circ}$ - $1.1^{\circ}$ ; after a 5 to 10-kilometer ski run, it increases: with the percale outfit, it increases by  $5.1^{\circ}$ - $5.6^{\circ}$ ; flannel outfit, increase by  $3.1^{\circ}$ - $6.5^{\circ}$ ; cheviot,  $2.5^{\circ}$ - $4.1^{\circ}$ , and with the velveteen outfit, the difference drops initially, and then increases significantly.

The greatest fluctuations of skin temperatures, with lower absolute values on the chest were observed with the flannel and cheviot outfits, although it must be noted that the higher and more even skin temperature with the percale outfit was attributed to the warmer underclothing rather than to the outfit. This was confirmed by measurements of the temperature of the air spaces between the clothing. The minimal skin temperatures observed on the chest ( $18.7^{\circ}$ - $21.0^{\circ}$ ) and the back ( $24.7^{\circ}$ - $25.3^{\circ}$ ) after a 10-kilometer ski run, show a significant chilling of the body; however, during the run there was no subjective sensation of cold. Complaints about chilling first occur three or four minutes after the skier has stopped.

TEMPERATURE OF SKIN AND AIR SPACES IN CLOTHING (AVERAGE DATA)

Таблица 1

Температура кожи и прослоек одежды (средние данные)

Материал костюма	Артикул	До опыта				После прохождения 5 км				После прохождения 10 км			
		Температура кожи		Температура прослойки		Температура кожи		Температура прослойки		Температура кожи		Температура прослойки	
		грудь	спина	грудь	спина	грудь	спина	грудь	спина	грудь	спина	грудь	спина
1) Полотно	AM-100	32,8°	31,5°	27,9°	28,4°	26,8°	28,6°	16,5°	21,6°	24,8°	25,5°	15,0°	20,8°
2) Байка	340	31,0°	32,1°	28,0°	28,4°	24,1°	27,5°	19,5°	25,6°	21,0°	28,1°	14,0°	20,5°
3) Шерсть	1895	31,0°	31,5°	28,9°	27,5°	21,9°	26,5°	18,4°	21,1°	18,7°	24,7°	16,2°	20,5°
4) Вельвет	472	33,2°	31,1°	28,7°	27,7°	23,8°	27,6°	20,5°	23,6°	22,9°	27,4°	21,8°	23,6°

LEGEND:

- 1) Outfit Material; 2) Article; 3) Before Test; 4) Skin temperature; 5) Temperature of Air Spaces; 6) Chest; 7) Back; 8) After covering 5 km. distance; 9) After covering 10 km. distance; 10) Percale; 11) Flannel; 12) Cheviot; 13) Velveteen.

To determine the wind resistant qualities of the outfits, temperature measurements of the clothing's air spaces and of the skin on the chest and back were taken on a still day. These results were contrasted with those under conditions of strong wind.

The data resulting from three comparative observations taken at the same atmospheric temperatures showed that the lowest chest skin temperature, depending on the wind, both at rest and during active skiing, was recorded with the cheviot outfit; the highest chest skin temperature, with the percale outfit. Conversely, the temperature of the air spaces between the clothing was more frequently lower under the percale outfit. This indicates that percale is not highly wind resistant, but its light weight permits one to wear two sets of underclothing, and in the final analysis, this gives better protection against the wind.

The temperature level of the skin and of the air spaces between the clothing depends to a large extent on the dampness of the clothing from perspiration. From this point of view, the determination of the over-all water-loss and the percentage of moisture absorbed by the clothing has a certain importance. In our experiments, the weight loss due to the evaporation of perspiration during a ski run of 10 kilometers averaged as follows: in the flannel outfit, 733 grams; in the percale outfit, 790 grams; in the cheviot, 1,058 grams; and in the velveteen, 1,100 grams. In spite of the high moisture loss with the cheviot outfit, the ratio of moisture absorbed into the cheviot as contrasted to the total weight of the outfit was lowest, 3.4%; with the percale outfit, it was 7.3%; with the flannel, 4.7%; and with the velveteen, 4.4%.

To determine the effect of the various outfits on the degree to which the underclothing is dampened (this has an important practical value), we sewed equal-sized pieces of cotton cloth into different locations in the outfits. The cloths were weighed before and after a ski run. The results of these experiments are shown in Table 2 [see following page], where we also indicate the data on measurements of the relative humidity of the air under the outfits.

It is evident that the degree of dampness of the underclothing and of the air under the ski outfits is quite significant. The underclothing was dampest, and the relative humidity of the air was highest, under the percale and velveteen outfits. Use of the other outfits resulted in noticeably lower levels, and were almost equal. The least dampness of underclothing was noted under the flannel outfit. Comparatively higher air humidity figures and degree of underclothing dampness were found on the back and at the waist, while the chest showed lower humidity figures. The great amount of wind that blows on the front part of the body explains these figures.

As indicated above, the tests on the various outfits were conducted with the use of cotton undergarments, the most common type in daily use. Obviously, using underclothing of other materials could influence the over-all hygienic qualities of the



TABLE 2

DEGREE OF UNDERCLOTHING DAMPNESS AND AMOUNT OF RELATIVE  
AIR HUMIDITY UNDER THE OUTFITS, IN PERCENTAGE  
(AVERAGE DATA).

Таблица 2  
Средняя увлажненность белья и величина относительной влажности воздуха под костюмами  
и процентная (средние данные)

① Материал костюма	② Статья	③ На груди		④ На спине		⑤ На поясе		⑥ На бедре	
		⑦ Увлажненность белья	⑧ Влажность воздуха	⑨ Увлажненность белья	⑩ Влажность воздуха	⑪ Увлажненность белья	⑫ Влажность воздуха	⑬ Увлажненность белья	⑭ Влажность воздуха
9 Шерсть . . . . .	1695	0.9	40	20.3	84	15.3	90	1.6	49
10 Фланель . . . . .	340	1.5	55	6.0	84	16.1	90	1.3	50
11 Вельветон . . . . .	472	1.7	80	31.1	90	16.0	100	1.3	49
12 Перкаль . . . . .	AM-100	6.6	63	37.4	95	32.8	100	5.3	84

## LEGEND:

- 1) Outfit Material; 2) Article; 3) On the Chest; 4) On the Back;  
5) At the Waist; 6) At the Hips; 7) Underclothing dampness;  
8) Air humidity; 9) Cheviot; 10) Flannel; 11) Velveteen; 12) Percale.

outfits. For this reason, additional tests were made with underclothing made of cotton crepe, knitted cotton, and a half-wool knit. In all cases, the velveteen outfit (Article 472) was worn over the underclothing. Weather conditions were the same. The average data on measurements of skin temperature and temperature of the air spaces between the outer and underclothing (obtained in these tests) are shown in Table 3 [see following page]. These data show that while the skier is in motion, the temperature indices are higher when underclothing made of half-wool knit is used. The temperature of the skin, and of the air spaces is almost the same with both the cotton crepe and the cotton knit.

Observations made in still weather, and during windy (2.3 meters/sec.) weather showed a sharper decline in the temperature indices, depending on the wind strength, with cotton-knit underclothing than with crepe. The latter weighed 50-100 grams less than the knit; after a ski run, the weight of the crepe increased by 100 grams, on an average, while that of the cotton-knit, by 200 grams, and the half-wool knit by 270 grams. The great drawback of the knitted underclothing as compared to the crepe was its greater weight and greater moisture-retaining quality.



TABLE 3

## TEMPERATURE OF SKIN AND AIR SPACES UNDER THE UNDERCLOTHING

Таблица 3

Температура кожи и воздушной прослойки под бельем

	(2) До опыта				(7) После прохождения 5 км				(8) После прохождения 10 км			
	температура кожи		температура прослойки		температура кожи		температура прослойки		температура кожи		температура прослойки	
	грудь (3)	спина (4)	грудь (5)	спина (6)	грудь (5)	спина (6)	грудь (5)	спина (6)	грудь (5)	спина (6)	грудь (5)	спина (6)
1) Белье из телячьей кожи												
4 Крен	31,0°	31,0°	27,4°	27,4°	27,2°	25,9°	14,7°	18,6°	25,8°	24,9°	15,1°	18,2°
10 Хлопчатобумажный трикотаж	31,8°	30,7°	26,8°	27,5°	27,7°	26,8°	15,5°	20,4°	25,1°	26,7°	17,7°	17,5°
11 Полушерстяной трикотаж	30,8°	30,9°	27,7°	27,2°	28,6°	29,5°	19,4°	23,0°	24,7°	27,7°	18,7°	23,0°
12 Бязь	32,7°	28,3°	28,0°	26,0°	26,0°	27,9°	18,6°	18,3°	22,9°	22,8°	21,8°	20,6°

## LEGEND:

- 1) Underclothing Material; 2) Before test; 3) Skin temperature; 4) Air space temperature;  
 5) Chest; 6) Back; 7) After covering 5 km. distance; 8) After covering 10 km. distance;  
 9) Crepe; 10) Cotton Knit; 11) Half-wool Knit; 12) Ordinary Cotton.

The degree of humidity loss was almost the same in the different kinds of underclothing. With the cotton knit, the body weight loss, after a 10-kilometer ski run, averaged 790 gms; half-wool knit, 690 gms; and crepe, 660 gms. We have already indicated that with the same velveteen outer garments, but using underclothing of cotton, the loss in body weight was considerably greater -- up to 1,100 gms; this, because air does not penetrate easily through ordinary cotton.

The quantity of moisture retained by crepe underwear averaged 4%; by ordinary cotton, 4.5%; half-wool knit, 5.1%; and the cotton knit, 5.4%. The underclothing was dampest on the back and at the waist; the ordinary cotton and crepe underclothing was considerably less moist than the other types. The relative air humidity was also lower under the crepe underclothing.

TABLE 4

DEGREE OF UNDERCLOTHING DAMPNES AND AMOUNT OF RELATIVE AIR HUMIDITY UNDER THE UNDERCLOTHING.

Таблица 4  
Степень увлажнения белья и величина относительной влажности воздуха под бельем в процентах

1) Бельевая ткань	2) На груди		3) На спине		4) На поясице		5) На бедре	
	6) Увлажнение белья	7) Влажность воздуха	6) Увлажнение белья	7) Влажность воздуха	6) Увлажнение белья	7) Влажность воздуха	6) Увлажнение белья	7) Влажность воздуха
8 Креп . . . . .	3,5	40	29,3	70	28,6	90	2,1	50
9 Хлопчатобумажный трикотаж . . . . .	14,3	80	45,5	90	97,3	100	10,0	49
10 Полушерстяной трикотаж . . . . .	18,3	84	24,7	100	84,4	100	3,5	60
11 Вязь . . . . .	2,6	74	18,6	90	14	90	6,1	55

LEGEND:

1) Underclothing Material; 2) On the Chest; 3) On the Back; 4) At the Waist; 5) At the Hips; 6) Underclothing dampness; 7) Air humidity; 8) Crepe; 9) Cotton Knit; 10) Half-wool Knit; 11) Ordinary Cotton.

CONCLUSIONS

1. Tests made on the most popularly used types of ski outfits manufactured for mass consumption showed that they do not guarantee the necessary constant micro-climate of the air spaces under the garments, because these materials do not allow air to penetrate adequately, and because they easily absorb and retain moisture.

2. Outfits made of cheviot are the best. However, since cheviot allows a high degree of air-penetration, these outfits do not afford sufficient protection to the body in low atmospheric temperatures and high winds. Under these conditions, an additional wind resistant jacket of a light, closely woven material is necessary. Another advantage of the cheviot costume is its adequate flexibility; it does not interfere with movement.

3. The use of flannel, cheviot, and velveteen outfits showed a significant difference between the surface skin temperatures of the chest and back (lower on the chest, especially in strong wind). This indicates the necessity of heavy protection against chilling of the front of the body.

4. Percale outfits, frequently favored by skiers because of their light weight, absorb perspiration moisture quickly, and become impermeable to air; they cause the underclothing to become quite wet, and raise the humidity of the air under the outfit. These outfits can induce a dangerously sudden cooling of the organism when skiing actions are decreased, or when the skier stops to rest. For wind resistant jackets, to be worn over a ski outfit, percale is a fully suitable material. Percale ski outfits should be used only with warm underclothing.

5. Flannel outfits are less practical; they quickly lose their nap, and then the physico-hygienic qualities of the material deteriorate.

6. Of the underclothing materials tested, the half-wool knit has the best heat conserving qualities, but it is relatively heavy, and absorbs a great deal of perspiration.

7. Crepe underclothing has a number of advantages: it guarantees optimum protection against wind, it is lighter, and does not become as moist with perspiration. The slightly rough, but at the same time adequately soft surface of crepe, prevents the material from sticking to the skin.

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